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AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

General Document 028

ROYAL AERONAUTICAL SOCIETY

33rd LAWRENCE HARGRAVE MEMORIAL LECTURE:

BRIDGING THE TECHNOLOGY GAP

by

G. L. BROWN

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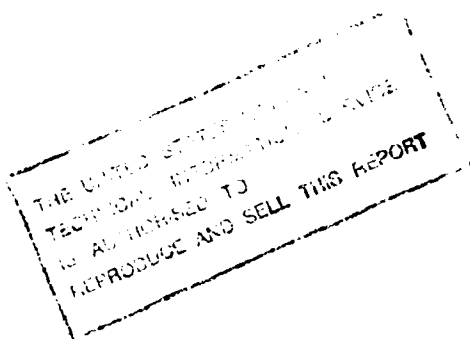
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**ROYAL AERONAUTICAL SOCIETY  
33rd LAWRENCE HARGRAVE MEMORIAL LECTURE:  
BRIDGING THE TECHNOLOGY GAP**

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**SUMMARY**

*In his lecture Dr Brown gives a personal view of why and how advances in aeronautics since the Wright Brothers' first flight occurred, where these advances seem to be leading and finally some implications and suggestions for Australia.*



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A simplistic but simple measure of the technological advances upon which these achievements were based is the thrust of the engines that made them possible.

- Wright Flyer engine - 90 lb
- Thrust of Whittle jet engine [maiden flight] - 860 lb
- Thrust of 747 engine - 60,000 lb
- Thrust of Saturn rocket - 7,500,000 lb *[Figure 5]*

In this lecture I would like to give a personal view about three things - Firstly, some brief reflections on why and how such advances in aeronautics occurred, secondly, where these advances seem to be leading us and thirdly, some implications for Australia.

or ☒ ☐ ☐

## 1. WHY AND HOW DID THESE ADVANCES OCCUR?

### 1.1 Why?

A first and simple answer is embodied in the 1983 Congressional statement by the Science Adviser to the President of the US [Dr George A. Keyworth II] on the Future of Aeronautics in the US:

*"We simply can't allow ourselves, nor will we accept any option in aeronautics other than pre-eminence. Aeronautics immense strategic potential, particularly for defense, dictates a vigorous research and technology plan, and demands a continued and strong Government involvement to ensure that adequate national investments are made in research and technology."*

Many evolving defence and civilian needs could be met most effectively by progressively advancing aeronautical systems.

At another level, however, aerospace developments were driven by the political recognition of a new frontier, the excitement of the challenge and a developing vision of unprecedented possibilities. This drive is symbolised by President Kennedy's response to Sputnik - to put a man on the moon within the decade:

*". . . I believe that this nation should commit itself to achieving the goal before this decade is out, of landing a man on the moon and returning him safely to Earth. No single space project will be more exciting or more impressive to mankind, or more important for long range exploration of space and none will be so difficult or expensive to accomplish."*

### 1.2 How?

Of course there could be as many answers to the question as people involved but I have answered it from the perspective of one who had a ring side seat for at least a part of it and with a

view to drawing some Australian comparisons and conclusions. I suggest that the following played an essential role:

- a deep underlying science base and a corresponding healthy philosophy about ignorance;
- an intense and decentralised market place;
- mechanisms to harness a national capability;

and I would like to say something about all three.

Feynman in his book 'What do you care what other people think' says that one of the great contributions of science to mankind has been a healthy philosophy about ignorance. Along these lines Fermi, another Nobel Laureate said, *"We learn by explaining to each other what we don't understand"* \*.

It is with such a philosophy, the antithesis of fanaticism, and in the open and honest environment of 'let's do an experiment', that technology [and many of our other endeavours] can flourish. Anyone who has lived in Southern California knows that this willingness to test another idea, which permeates and stimulates many facets of community life, is an essential part of the culture and in my view it plays a critical role in any technological enterprise [including the management of it!].

An intense and decentralised market place is the second key factor which accounts for how such rapid advances in aeronautics could occur. As the Eastern bloc has now also realised, it is healthy competition that propels much human endeavour and Australians with our love of sport, know it well. More than propelling human endeavour, however, an intense market place opens up options, and allows choice at many levels of detail. Technological advance and achievement depend upon good and affordable ideas floating to the top. [I am reminded of the New Yorker cartoon at the time of the Apollo program in which one astronaut says to the other just before lift-off - just remember every component was built by the lowest bidder!]

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\* A colleague familiar with this remark was not certain whether it was due to Fermi or to Oppenheimer.

The third key factor in explaining how such rapid advances occurred is the mechanisms, established in peace-time, to harness a national capability. Amongst the most important of these mechanisms have been funding agencies for research and development, contract mechanisms, and national advisory boards. The recognition that 'he who hath the gold hath the power' [Augustine] and the importance of a customer/private enterprise supplier relationship enabled the US to marshal 20,000 subcontractors and 350,000 people for the Apollo program in such a short time.

## **2. SOME FUTURE DIRECTIONS**

Before turning to more local issues I would like to draw attention to where these advances seem to be leading us.

The most significant consequence of these advances has been the irreversible change in our understanding of other peoples of the world and in our relationship to the world as a planet.

The break-up of the Berlin Wall began in people's minds long before it occurred physically and surely this change in attitudes owes most to modern mobility made possible by the airline networks of the world and by the communication and real time coverage of international events through satellite communication systems.

More subtly, satellite intelligence systems have reduced the possibility of massive covert preparations for war and have allowed international negotiations to proceed from a basis of indisputable fact. As I watched the dawn service at Gallipoli this past Anzac Day I was thinking [thankfully] that such a sea invasion is not likely to happen again: with satellites and infra-red and other sensors there could be no expectation that storming the beaches of a foreign land, as dawn broke, would be a surprise.

Notwithstanding Ireland, the Middle East and even some shadows in the recent events of eastern Europe surely mobility, and satellite communications and intelligence have reduced 'tribalism' on a global scale. The President of the US now seeks a gentler and more humane America. Such a change reflects new attitudes and more manageable tensions in the world.

Aerospace developments will continue to play a leading role because of:

- the demand for long distance travel for more and more people, particularly in a world of more manageable political tensions and increased global trade.
- the right to defend national sovereignty.
- the expected as well as unanticipated benefits from advancing our understanding of ourselves, our planet and the universe through space exploration.
- the need for 'stewardship' [as Prince Charles described it] of our planet.

And in anticipation of this role the US aerospace industry is developing strategies which again emphasise:

- a strong technology base
- the market place
- mechanisms to harness national capability.

For example, the Aerospace Industries Association of America, established in 1989 the National Centre for Advanced Technologies [NCAT] - a non-profit foundation for integrating and coordinating AIA's Key Technologies for the 1990's program, and assisting in its implementation.

The AIA Key Technologies for the 1990's are:



- 
- Advanced composites
  - Advanced sensors
  - Airbreathing propulsion
  - Rocket Propulsion
  - Artificial Intelligence
  - Computational Science
  - Optical Information Processing
  - Software development
  - Superconductivity
  - Ultra-reliable electronic systems

Recently the US Department of Defense identified 22 critical technologies of major importance to national security. A comparison with AIA's broader categorisation shows a close match with 15 of the 22 critical technologies identified by the Department of Defense.

The principal objectives of the NCAT are to:

- Develop national consensus and support for Key Technologies.
- Support adequate and stable funding in the federal budget for an adequate technology base and also for specific Key Technologies.
- Utilise industry and government to adopt the Key Technologies development plans as their strategic research and development plans.
- Provide counsel to government departments, agencies and others, regarding technology integration, planning and policy.
- Act as an impartial bridge between industry, the administration and Congress to encourage adequate and continuous support of all technology-related resources, such as manufacturing processes, testing

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and evaluation, and the education of science and technical personnel.

*"The NCAT is a new concept bringing together through direct industry sponsorship and support the best thinking available in government, universities, and corporations to develop nationwide understanding and consensus on a most important matter - the future technological strength of our nation."*

The overall goals of the Key Technologies program are to 'leap-frog' present state-of-the-art system capabilities, reduce the development time to approximately half that now required, and cut development cost significantly. *"The overriding aim is to ensure continuing US aerospace competitive superiority as we enter the next century - superiority in terms of technology, quality, service and cost."*

In these goals there is a clear aim to increase productivity but not through people working twice as hard, or through new management techniques or by political decree; while better management is important the heart of the matter is the development and application of technology. It is computer-aided engineering and other technologies which the AIA has in mind in proclaiming the productivity goal to cut development time by one half.

This new initiative illustrates the importance placed on the national technology base and particularly on the selected technologies upon which a major national industry [aerospace] depends. It also illustrates the emphasis on integrating and harnessing this national capability.

Similarly there is a focus on the growing world market and the 'internationalisation' of the aerospace industry. In 1989 the world's scheduled airlines carried 1,120,000,000 passengers. The US airline fleet is approximately 4000 aeroplanes and recently US manufacturers had orders on their books for 1800 aircraft worth some \$77 billion of which orders from foreign customers amounted to \$48 billion [i.e. 63 per cent]. The European

community's drive toward the establishment of a single market of 12 member states by 1992 has focussed further attention on international ventures and collaboration. The largest civilian aerospace market projected for the first quarter of the 21st century appears to be the Pacific rim. It links the western US with Japan and the emerging powers of Korea, Singapore, Malaysia, Taiwan and China. This emphasis on internationalisation and the projected market for the Pacific rim and in the context I have described, brings me finally to:

### 3. SOME IMPLICATIONS FOR AUSTRALIA

In a recent talk Mr W.A. Kricker, Chairman of the Australian Industry, Research and Development Board drew attention to the fact that in 1988/89 exports earned \$54 billion, whereas imports including debt service payments cost \$72 billion. We, therefore, added \$18 billion to our net external debt which in mid 1989 stood at \$108 billion or 31 per cent of Australia's GDP. The profile of these exports is as follows:

	<b>\$B</b>
Rural	15.6
Ores, Minerals and Mineral fuels	12.6
Metal	7.4
Manufacturing	<u>7.2</u>
Merchandise Exports	42.8
Services	11.0

**TOTAL 53.8**

Notwithstanding our technological knowledge and our appetite for manufactured goods, including modern military and commercial aircraft, Australia is a very minor force in world manufacturing markets. For example, our total manufacturing exports in 88/89 represent about 10 per cent of foreign orders on

the books for US commercial aircraft alone. More specifically our top four manufacturing exports\* for Australia are:

	<b>Exports \$B 88/89</b>
BHP	.739
Simmsmetal	.175
Hawker de Havilland	.125
Nucleus	.100

[This list excludes multi-national offshoots with limited mandates and businesses whose presence depends primarily on resource advantage.]

Turning to our people as a source of our technology base and speaking from my knowledge of university research through the Australian Research Council and from participation on an engineering faculty I would broadly conclude that:

- engineering departments in Australian universities are finding it more difficult to recruit staff with an international reputation.
- engineering departments have relatively poor facilities and on the whole there is relatively little research in the critical enabling technologies.
- relatively fewer bright students today are choosing courses in science and engineering. The cut off score at Melbourne, for example, for law is 364, for medicine 361, for engineering 301 and for science it is 279!

This overall situation, therefore, both in terms of our manufacturing exports and in terms of our technology base in universities reflects the underlying fact that Australia is not making and has not made much money out of its technological capability.

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\* W.A.Kricker 'Research in Australia. What are we trying to do? How do we achieve it?' University of Melbourne, March 1990. Research Policy in Higher Education

Some would argue that this situation is simply the market at work - Australia has no comparative advantage in manufacturing. Others, of whom I am one, believe that we have not at all made the most of our opportunities.

Nobody, for example, could look at the structure of aeronautics in Australia - Hawker de Havilland, the Commonwealth Aircraft Corporation [owned, it has been said, by more or less disinterested parties], the Government Aircraft Factory [wholly placed within a Department of State and run under Public Service procedures] - and the Aeronautical Research Laboratory [wholly within the Department of Defence and largely isolated from all three companies] and wonder whether it was structured to make money.

Similarly the Coombes Royal Commission of 1976, the two DSTO reviews of 1980 and ASTEC in 1986, and particularly the submissions to those reviews, show that ARL, a national research and development asset, had been shackled through insularity and a rigorously imposed management philosophy of centralised control.

In 1980 the Independent External Review of DSTO said of ARL:

*"7.23 The combination of a lack of cohesive leadership, a lack of flexibility, a lack of adequate equipment, the residue of researchers in the later stages of their careers, and the increasing demands for short-term solutions, has had a depressing effect on the ethos of ARL. There is a pervading atmosphere of frustration and a wistful desire to return to the halcyon days when the Establishment was at the peak of its performance."*

The ARL Program Evaluation, December 1989 Report, notes that:

*". . . Despite the various reviews of DSTO and its elements over the past 10 years, and the best intentions expressed in government responses, many problems were deeply entrenched*

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*and extraordinarily difficult for a Laboratory to overcome essentially because the solutions implied significant change."*

When I arrived in 1981 my secretary had a manual typewriter. Similarly, it was a matter of incredulity to me that as the Director I was not responsible for the five year plan for the Laboratory but rather it was developed centrally by staff unfamiliar with aeronautical research.

In terms of the factors which played a critical role in the advances of aerospace:

- a deep science base and a healthy philosophy about ignorance
- an intense market place
- mechanisms to harness the national capability

ARL was:

- relatively isolated from universities and international centres and able to manage its people and move the money around only with the greatest difficulty. [In terms of successful international R&D management practices it was subject to management direction by outside agencies who did not know they did not know.]
- not in a strong customer/supplier relationship for work sponsored by the Australian Defence Force and unable to work with the Australian or international aerospace industry except on projects for the ADF.
- without a management Board and [apart from Professional Societies] essentially isolated from other elements of the national capability except through the creation of an 'R&D Authority' structure for particular projects.

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This is not intended in any way as a criticism of the Laboratory but rather of the vision and system imposed upon it. Put simply, in my view, it is a tribute to the resilience of the staff and the spirit of our forebears that the Laboratory continued to make the substantial technological contributions that it did. For those who would like to understand some of the reasons why Australia has made so little from its technological capability, however, its files and the submissions to the above four reviews would be a good place to begin.

Tonight, however, I bring you good news - all of us at ARL would describe a different picture today. We have sought to build new bridges to the national and international industry, new bridges to universities, and new bridges to international laboratories and aerospace R&D centres. We have also sought to strengthen our science and particularly our program of work for our primary customer, the Australian Defence Force, develop our people, establish modern facilities, and allocate directly and manage our money to achieve our objectives.

It is not possible to do more in this lecture than to illustrate some of these directions.

*Figure 6* shows the recent development of a new technique to simultaneously apply the slowly varying manoeuvre loads as well as the dynamic [buffet] loads to an aircraft structure. This combination of loads is important in determining the fatigue life of the aft fuselage, tailplane and fin of the F/A-18. It was also poorly predicted by the designer and the fatigue test that the manufacturer carried out has not provided Australia with an adequate basis upon which to assess the life of the structure under RAAF usage. The very satisfactory outcome of the Laboratory's development and demonstration program completed a first preliminary phase at ARL of a joint Canadian and Australian full-scale fatigue test of the F/A-18.

*Figure 7* shows a model of the F/A-18 in our water tunnel and the dye marks the longitudinal vortex, springing from the leading edge

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extensions, which at particular angles of attack 'bursts' ahead of the fin. This vortex 'breakdown', as it has been called, leads to a large scale unsteadiness in the flow over the fin and tailplane which drives the resonant modes of the structure. It explains why the combination of manoeuvre and dynamic loads and its effect on the life of the structure has been poorly predicted. In the last few years ARL has made significant progress in understanding the underlying physics of the vortex 'breakdown' phenomenon [first identified in the 1950's in studies which preceded the development of Concorde]. This work has led to new collaborative arrangements with overseas R&D centres and offers some prospect of affecting the vibration at its source.

*Figure 8* illustrates our recent developments in the assessment of combat effectiveness. Advances in simulation, direct inputs from the Services, and our development, with the help of other DSTO laboratories, of accurate and extensive models of the flight mechanics of aircraft and weapons and of sensors etc. enable us today to make valuable contributions to the assessment of our military aircraft, their systems and tactics in various scenarios.

It is a sense of an R&D Laboratory with a clear mission and a program to meet a national requirement but with strong bridges to other elements of our national capability and, most importantly, the ability to bridge the inevitable technology gap with the rest of the world, which I had in mind when choosing the title for this talk. Australia must support first rate research groups since it is people who bridge the technology gap and those in first rate groups have the necessary international linkages and networks to bridge the gap.

More generally, and in closing, I conclude that Australia can make more money out of its technological capability and in terms of the three factors which I have emphasised I would make the following recommendations:



1. TECHNOLOGY BASE

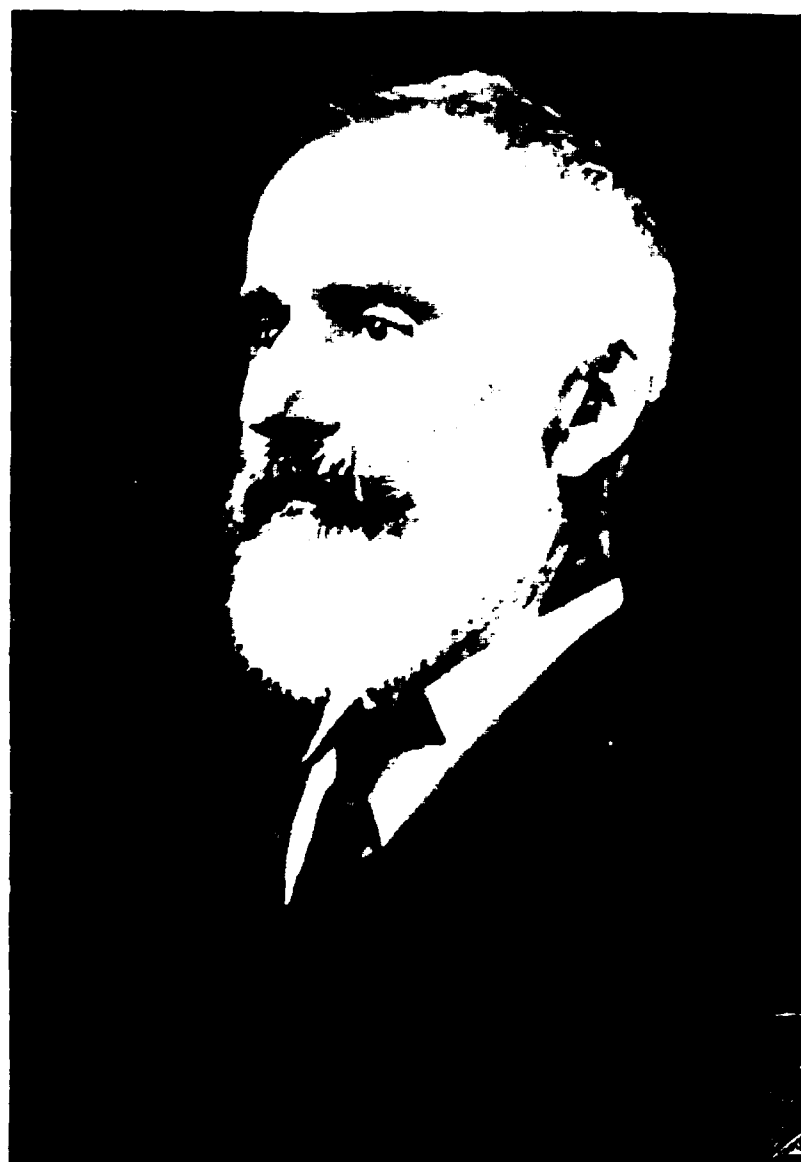
- A more flexible approach to Academic salaries.
- Some new University Research Centres well coupled to national R&D Laboratories.
- Separate funding for Key Technologies.

2. MARKET PLACE

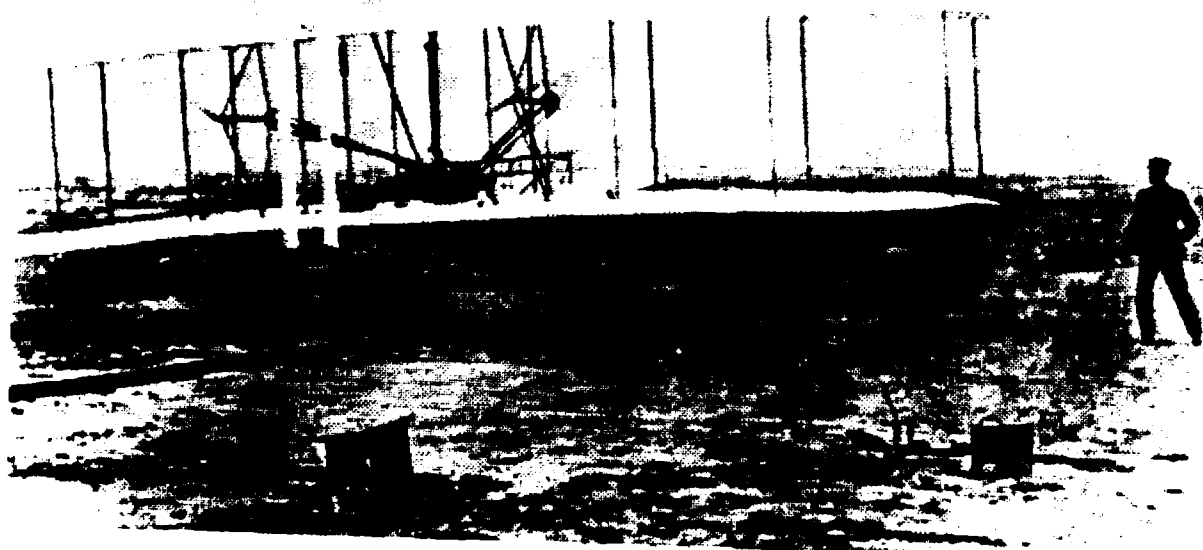
- The development in general of stronger Customer/Supplier relationships.
- The exploitation of particular niches such as overhaul, maintenance, refurbishment and avionics updates in aircraft. There are a number of reasons why Australia has a strong technology base in this area and has particular market strengths.
- Decentralise.

3. MECHANISMS TO HARNESS THE NATIONAL CAPABILITY

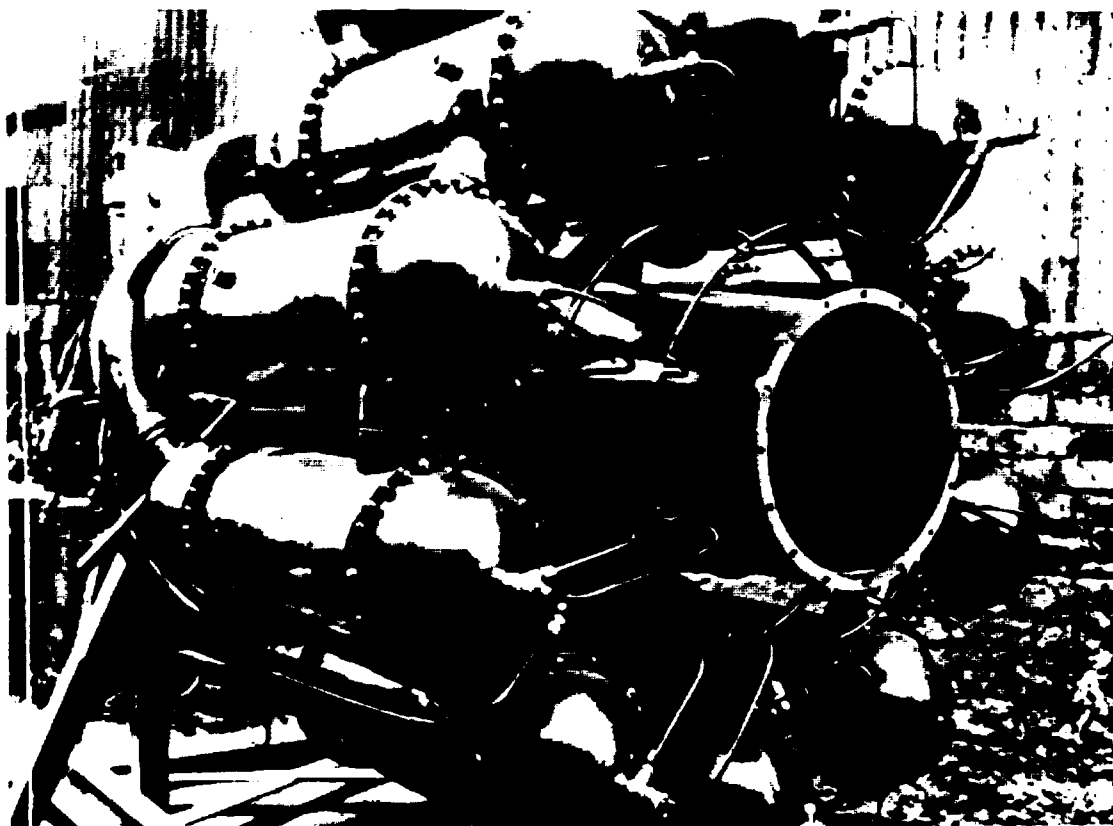
- Recognise that productivity gains are essentially based on technology notwithstanding the gains to be made through improved management practices.
- Establish management boards for National R&D Assets.
- Establish an entity involving Industry CEO's, Academia and National Laboratories to Support Key Technologies.
- Establish more short term Advisory Boards and Committees with specific responsibilities for determining priorities.



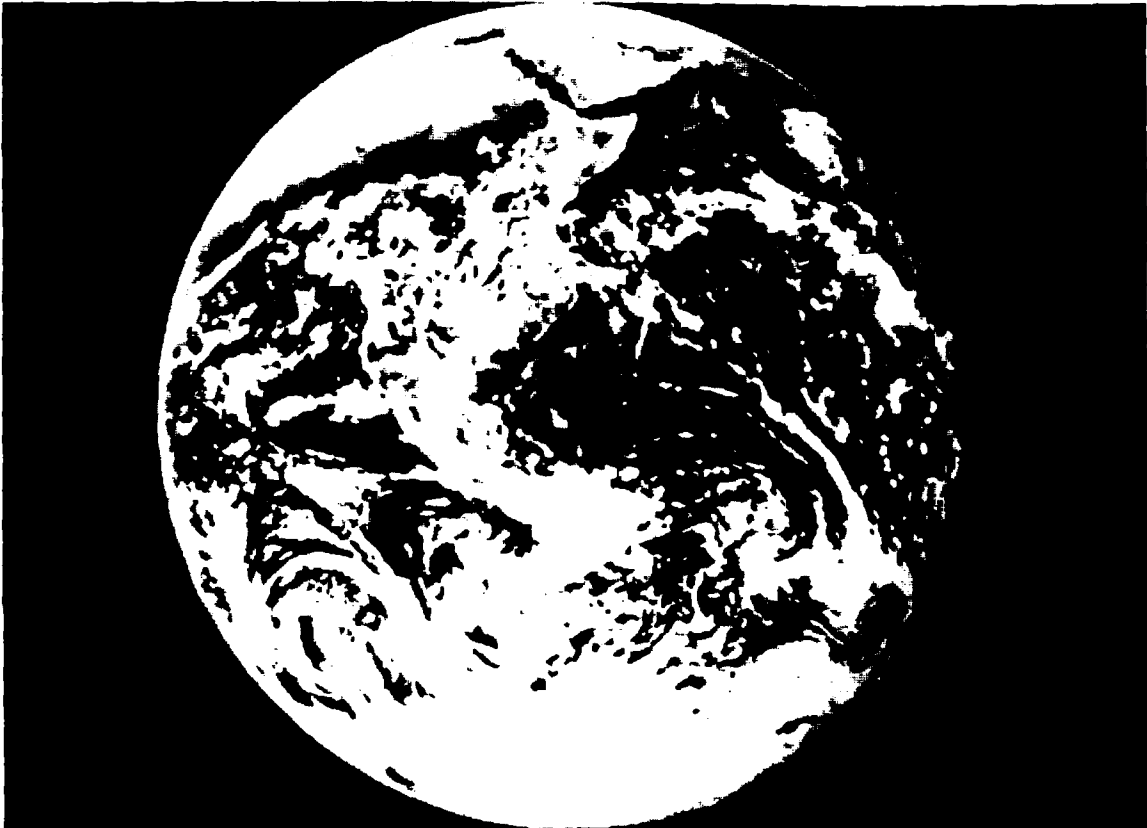
**FIGURE 1:** Lawrence Hargrave



**FIGURE 2:** First powered flight, 17 December 1903: Orville Wright flying, Wilbur Wright standing by. *[Subject to copyright - copied from F.E.C. Culick GALCIT the first 50 years.]*



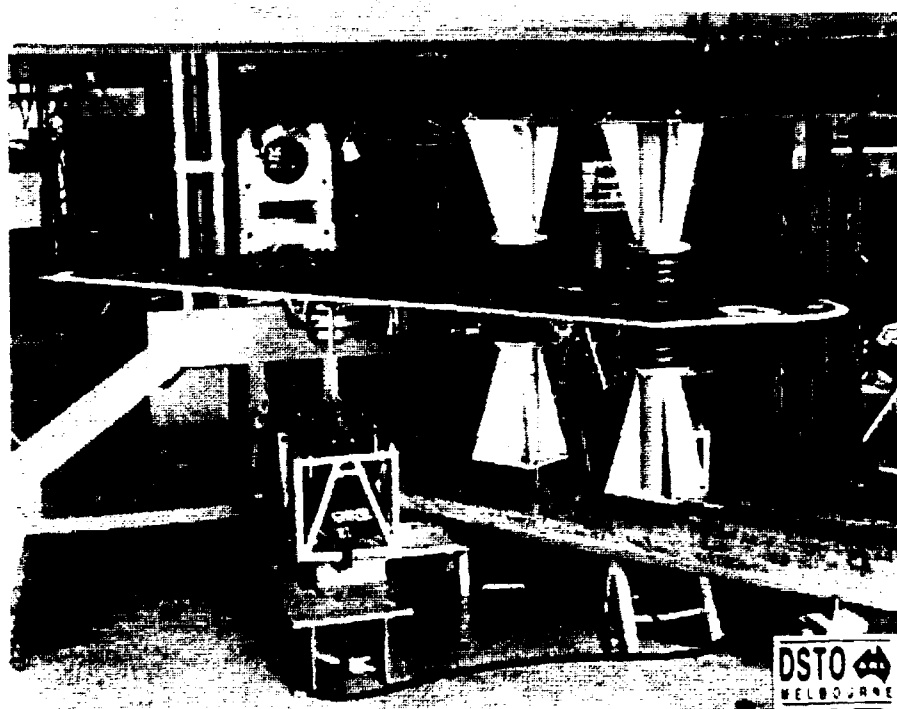
**FIGURE 3:** Sir Frank Whittle's engine which powered the first jet flight on May 15, 1941.



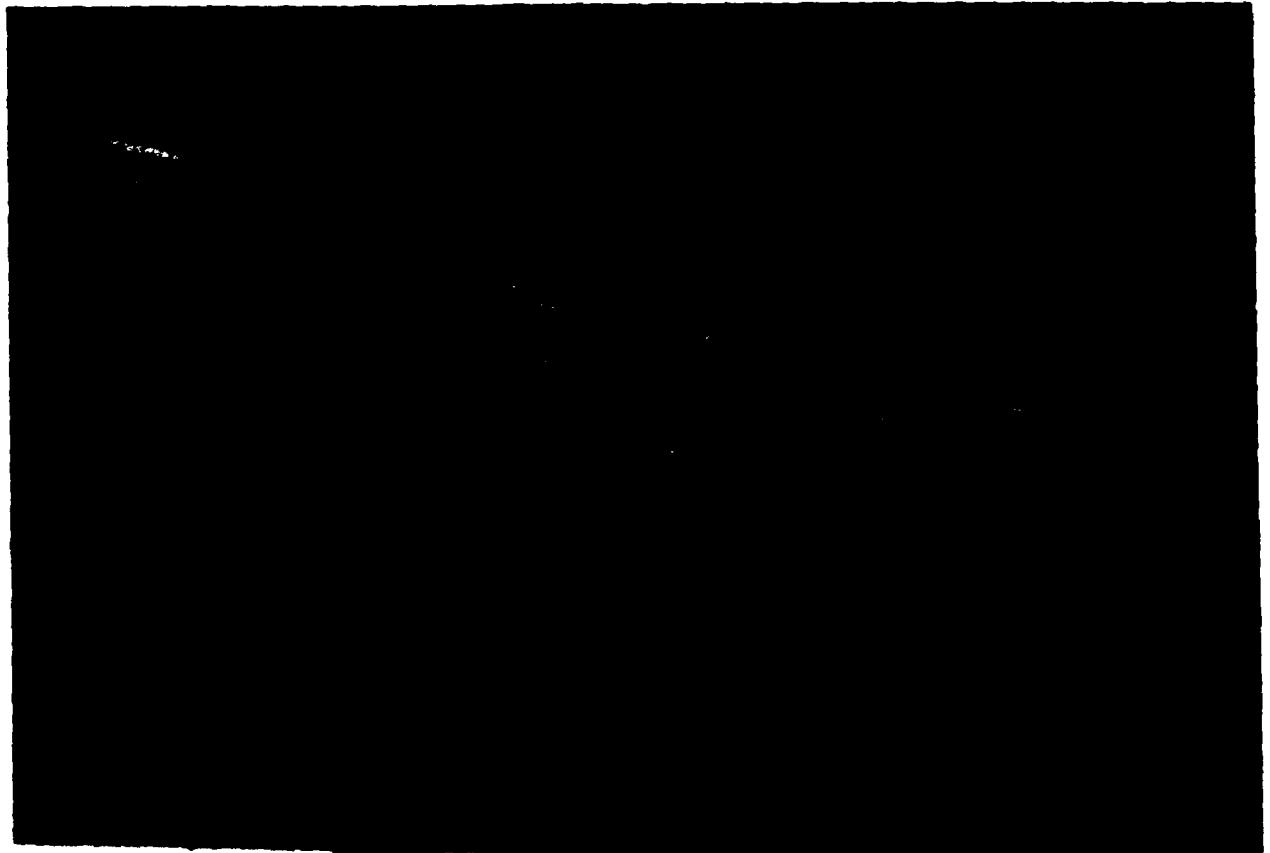
**FIGURE 4:** A view of planet Earth from the Apollo 17 journey to the moon. [*Copy from 'Man's Greatest Adventure.'*]



**FIGURE 5:** An early test firing of a Saturn V rocket in a Californian Canyon.



**FIGURE 6:** An early test of a pneumatic loading system for the application of manoeuvre and dynamic loads to the F/A-18.



**FIGURE 7:** Vortex 'breakdown' in the flow over an F/A-18 model at high angles of attack. [*Courtesy Dr D.H. Thompson, ARL.*]





**FIGURE 8:** A display of an accurate simulation of aircraft, weapons, sensors and other systems in combat.

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SPARES ( 50 copies)

TOTAL (102 copies)

## DOCUMENT CONTROL DATA

PAGE CLASSIFICATION  
UNCLASSIFIED

PRIVACY MARKING

1a. AR NUMBER AR-006-114	1b. ESTABLISHMENT NUMBER ARL-GD-028	2. DOCUMENT DATE JULY 1990	3. TASK NUMBER -
4. TITLE ROYAL AERONAUTICAL SOCIETY 33rd LAWRENCE HARGRAVE MEMORIAL LECTURE: BRIDGING THE TECHNOLOGY GAP		5. SECURITY CLASSIFICATION (PLACE APPROPRIATE CLASSIFICATION IN BOX(S) IE. SECRET (S), CONF. (C)  RESTRICTED (R), UNCLASSIFIED (U) ).  <div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid black; padding: 2px; text-align: center;">U DOCUMENT</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">U TITLE</div> <div style="border: 1px solid black; padding: 2px; text-align: center;">U ABSTRACT</div> </div>	6. NO. PAGES  21  7. NO. REFS.  -
8. AUTHOR(S)  G.L. BROWN		9. DOWNGRADING/DELIMITING INSTRUCTIONS  Not applicable	
10. CORPORATE AUTHOR AND ADDRESS AERONAUTICAL RESEARCH LABORATORY  P.O. BOX 4331, MELBOURNE VIC 3001		11. OFFICE/POSITION RESPONSIBLE FOR: SPONSOR _____ SECURITY _____ DOWNGRADING _____ APPROVAL <b>DARL</b>	
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14. DESCRIPTORS Aeronautics Aeronautical research Research and development Australia			15. DISCAT SUBJECT CATEGORIES  0101 010312
16. ABSTRACT  <i>In his lecture Dr Brown gives a personal view of why and how advances in aeronautics since the Wright Brothers' first flight occurred, where these advances seem to be leading and finally some implications and suggestions for Australia.</i>			

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**UNCLASSIFIED**

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16. ABSTRACT (CONT):

17. IMPRINT

**AERONAUTICAL RESEARCH LABORATORY, MELBOURNE**

18. DOCUMENT SERIES AND NUMBER

*General Document 028*

19. COST CODE

10 0001

20. TYPE OF REPORT AND PERIOD COVERED

21. COMPUTER PROGRAMS USED

22. ESTABLISHMENT FILE REF.(S)

23. ADDITIONAL INFORMATION (AS REQUIRED)